ABSTRACT
The aim of this doctoral dissertation was to develop an innovative butt-welding technology for two-layer composite pipes using laser and hybrid methods (laser + MAG), enabling the production of joints that meet the quality requirements specified in PN-EN ISO 13919-1:2020, PN-EN ISO 12932, as well as the operational requirements of the energy industry. The developed method makes it possible to produce welds of high metallurgical quality, homogeneous microstructure, and required mechanical properties, in compliance with stringent quality and operational standards. The process was qualified in accordance with PN-EN ISO 15614-11 and PN-EN ISO 15614-14, and the solution was granted patent protection (P.435026), underlining its innovative character and implementation potential.

The dissertation consists of two main parts. The first part provides a review of domestic and international literature, covering the theoretical foundations of laser welding and hybrid technologies, the characteristics of materials used in composite pipes, as well as other methods of welding composite pipes and applying coatings to pipes. Particular attention was paid to issues related to microstructure, mechanical properties, corrosion resistance, and creep, which are critical for components operating in high-temperature and chemically aggressive environments.

In the second, research part, the thesis and objectives of the study were formulated, a research methodology was developed, and a comprehensive evaluation of laser welding and hybrid cladding technologies was carried out. The investigations included:
• Non-destructive testing, including:

- visual inspection and penetrant testing for surface weld evaluation,
- radiographic testing for detection of internal discontinuities,
- eddy current testing,
- stress analysis in the welded joint using radiographic methods.
  • Destructive testing, including:
- tensile tests to determine strength and ductility of joints,
- bend tests to evaluate metallurgical continuity and deformation resistance,
- hardness measurements across weld cross-sections and heat-affected zones,
- micro- and macrostructural observations using light microscopy and scanning electron microscopy (SEM/EDS).

The conducted analysis allowed for an assessment of joint quality in relation to normative requirements and indicated areas requiring further optimization. Joints produced using laser and hybrid methods demonstrated high repeatability, narrow heat-affected zones, and structural stability, which is of significant importance for their application in the energy and chemical industries.

The conclusions of the dissertation confirmed that the use of laser and hybrid technologies makes it possible to obtain joints that meet stringent quality and operational requirements. The developed method may find wide application in energy and chemical installations, contributing to extended service life, reduced operational costs, and improved safety of pressure equipment. Future research should focus on evaluating the fatigue and corrosion durability of joints under long-term service conditions, optimizing filler materials, and developing adaptive process control systems.

Keywords: laser welding, hybrid cladding, composite pipes, microstructure, mechanical properties, destructive testing, non-destructive testing, energy industry, welding technology evaluation